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AN EVALUATION GUIDE FOR ARMY AVIATION HUMAN FACTORS ENGINEERING REQUIREMENTS

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HUMAN ENGINEERING LABORATORIES

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HEL Standard S-4-65

An Evaluation Guide for Army Aviation Human Factors Engineering Requirements

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ABSTRACT

The U.S. Army Human Engineering Laboratories (HEL) have developed a guide, including criteria for evaluating both the technical aspects of a proposed design, and the Quality Assurance provisions for a contractor's human factors engineering program plan.

This model for Army Aviation Materiel was developed to satisfy a number of objectives:

1. Clarifying the intent of HEL Standard S-4-65 (25).

2. Giving contractors better guidance so they can improve the human factors sections of design proposals.

3. Giving U.S. Army Materiel Command project managers a clearer understanding of human factors evaluation techniques and the scope of evaluations, as well as the overall scope of human factors programs.

4. Providing a guideline for Government personnel who must evaluate the human factors adequacy of aviation materiel.

References indicate selected human factors criteria and methodology that both contractor and U.S. Army personnel should use during evaluations.

AN EVALUATION GUIDE FOR ARMY AVIATION

HUMAN FACTORS ENGINEERING REQUIREMENTS

INTRODUCTION

During the past 20 years, the technical specialty of human factors engineering has grown into prominence because both industrial organizations and Government agencies realized that the man-machine aspects of military systems and equipment design were not getting adequate attention. As a result, principles were developed for incorporating human factors engineering in design, and requirements were gradually imposed on producers of military systems to implement these principles during the design and development. The literature is virtually saturated with reports about design principles and methodologies for developing, applying and validating human engineering data. In addition, as military systems became more complex, the requirements imposed on industry became more stringent. Requirement-setting documents (1 through 7, 57, 58, 62 through 66, 78, 106, 125) began to appear in profusion. It was found that adequate incorporation of human engineering design principles could be assured only by detailed specification of requirements. Thus there are now a number of specifications, standards, and technical exhibits about human factors, each with its own distinctive flavor arising from the particular requirements of the Department of Defense agency that originated it.

The mission of USAHEL, as defined by AMC Regulation 10-4 (15), encompasses the following:

a. Performing human factors research and engineering as directed by Headquarters, AMC.

b. Monitoring of the total AMC human factors program.

c. Conducting human factors research and engineering as requested by the AMC subordinate commands and project managers.

d. Assuring that AMC materiel evolved conforms with the capabilities and limitations of the fully-equipped soldier to operate and maintain the materiel in its operational environment consistent with tactical requirements and logistic capabilities.

In line with this trend, the U.S. Army Human Engineering Laboratories (HEL) have recently issued HEL Standard S-4-65, Human Factors Requirements for Development of U.S. Army Materiel (25). This document elaborates upon

AMCPI 7-380 (14), an extremely broad statement intended to assure that human factors requirements will be incorporated into contract clauses. HEL Standard S-4-65 represents HEL's official position. It establishes requirements to assure that contractors will (1) efficiently integrate the man into the design of Army materiel, and (2) furnish the information and data necessary to evaluate the contractor's compliance with the requirements stated therein. The document includes requirements in the following areas:

1. General requirements

a. Human factors sections of proposals for U.S. Army Materiel Command systems and equipment

2. Detail requirements

a. Guidance Meeting

b. Systems Analysis

c. Equipment and Facilities Design

d. Task and Skill Analysis

e. Test and Evaluation

f. Reports and HFE Data

g. Compliance

HEL Standard S-4-65 (25) is, of necessity, a broadly stated guidance document which does not impose rigid analytic formats or equipment design criteria. It is very similar to other specifications in existence, but it places heavier emphasis on design-oriented activities, rather than vast, iterative analyses to substantiate personnel skill selection, training equipment requirements, and Technical Manuals, as the Air Force Personnel Subsystem program does.

HEL Standard S-4-65 should provide the basis for sufficient information and data about a specific system so that a human engineer working for a government agency will be armed with the facts he needs to assess the system's technical adequacy.

It should be stated that HEL Standard S-4-65 applies to procurement of all Army systems, regardless of whether they are of a research nature, or full-scale developmental systems. However, the degree to which the standard's requirements will be imposed necessarily depends on several system characteristics:

a. Degree of "newness" - If the system to be developed is an advancement in the state-of-the-art - for example, an operational tilt-wing aircraft with advanced reconnaissance sensors - then quite obviously, the full requirements of the standard will be applicable.

b. Degree of complexity - If the equipment to be developed is a subsystem of a larger system already in service, then limited provisions of the standard will be applicable.

c. Phase of development - Human factors engineering principles must be emphasized in the initial phase of system development. Accordingly, much of the effort the standard requires should take place during Contract Definition or early development phases.

The degree to which the provisions of the standard are imposed on specific projects will depend on the mutual agreement of the U.S. Army Human Engineering Laboratories' contractor monitor, and the procuring activity.

Perhaps the most difficult problem faced by the human engineer responsible for evaluating equipment design concepts in proposals for Army aircraft is that the content and format of information submitted by contractors varies considerably from proposal to proposal. Therefore, the criteria given here constitute both a tool to help the individual human factors proposal evaluator compare the technical qualities of various designs and a guideline to help him meet the requirements of HEL Standard S-4-65 in his section of a design proposal.

For a further discussion of the responsibilities of the various activities contributing to the overall human factors program in the Army, refer to Baker (23). The basis of the total human factors program is Army Regulation 70-8, entitled Human Factors and Nonmateriel Special Operations Research (18).

PURPOSE

The purpose of this report, then, is to acquaint the reader with a human factors model, developed by HEL, for evaluating aircraft designs. This model has evolved as a result of experience gained on a number of current aircraft which are undergoing development. It is intended that the report will satisfy these objectives:

a. <u>Clarify intent of HEL Standard S-4-65 (25)</u>

The evaluation model which is described herein attempts to elaborate on elements in the subject document which are set forth as broad contractual requirements.

b. <u>Provide a "road map" for prospective contractors</u>

The evaluation model should provide potential contractors with a better understanding of how proposals will be evaluated. It further seeks to delineate analyses and data which should be provided by contractors to substantiate their proposed designs. This in turn should result in technical proposals which are both complete and responsive to human factors requirements.

c. <u>Provide guidelines to USAMC project managers</u>

The evaluation model should give Army project managers a clearer understanding of the scope of a human factors evaluation, as well as the overall scope of human factors programs.

d. <u>Provide prospective evaluators with current evaluation techniques</u>

The evaluation model should assist the proposal evaluator in conducting a thorough technical evaluation in the area of human factors. This should, in addition, result in an evaluation approach which is standardized within practical limits.

RELATIONSHIP OF HUMAN FACTORS ENGINEERING TO MISSION REQUIREMENTS

Certainly no discussion of a human engineering evaluation model would be complete without some mention of mission requirements, or the operational suitability aspects of the system, since these factors must be considered as mutually dependent. A design may inherently possess all of the classical human engineering characteristics known to man, but if it is not capable of performing the stated mission(s) it is operationally unsuitable.

It is for this reason that any evaluation of an Army aircraft from the human engineering point of view must be based on a knowledge of those factors which relate to the overall mission requirements, and will be closely coordinated with personnel who are drawn from user activities. Generally, personnel from such organizations as the U.S. Army Combat Developments Command, the U.S. Army Aviation School, the U.S. Army Board for Aviation Accident Research, as well as operational units, all provide this user knowledge.

The overall mission of Army aviation is "to augment the capability of the Army to conduct effective combat operations." This mission (12) is accomplished by five major functions:

a. Command, liaison, courier, and communications - including aerial wire laying and aviation to assist in the direction, coordination, and control of Army forces in the field.

b. Observation, visual and photographic reconnaissance, fire adjustment and topographic survey - including aerial observation to amplify and supplement other Army methods of observation for the purpose of locating, verifying and evaluating targets; adjusting fire; terrain study, or obtaining information on enemy forces.

c. Airlift of Army personnel and materiel - including movement of units to execute airlanded operations, the movement of reserves, and the shifting and relocation of units within the combat zone. It also includes expeditious movement of critically needed supplies or equipment.

d. Aeromedical evacuation - including battlefield pickup of casualties, air transport to initial point of treatment or hospital facilities within the Army combat zone.

e. Fire suppression - provides the ground commander with responsive and immediately available aircraft to fill his need for fires in an offensive or defensive situation. These aircraft will have the capability of providing armed escort for airmobile operations.

Each of the above missions can be characterized by the following system objectives which have been extracted from Reference 12:

"1. VTOL and STOL Capability - operation in forward combat areas will require all Army aircraft to be capable of landing and taking off from unprepared terrain.

2. A High Ratio of Maximum Speed to Minimum Speed - the flying qualities must remain first-rate throughout the wide range of speed.

3. Ease of Maintenance - available Army personnel must be able to maintain the aircraft with available Army equipment in the field.

4. Mobility or Transportability - aircraft must be either capable of being flown to the deployment area or be air transportable in Air Force aircraft.

5. All-Weather, Day and Night Capability - in some cases, the type of all-weather capability required may be closer to that required of a truck than that required of commercial airline transports.

6. Inherent Passive Defense Measures - noise reduction, absence of prohibitive dust-raising downwash velocities, and relative invulnerability to detection and firepower [through nap-of-the-earth altitude flight]* are necessary.

7. A Reasonable Degree of Flight Safety and Crash Safety - these must be provided with particular attention to nap-of-the-earth mode of operation which is often slow or hovering."

Each of the aforementioned broad system objectives is literally fraught with human factors engineering implications, as can be readily seen. Human factors engineering evaluation criteria then must, in conjunction with criteria of other technical specialties, adequately satisfy those objectives.

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*Words in brackets are author's comments.

DESCRIPTION OF EVALUATION MODEL

The human factors evaluation model, then, is directed to answering the following questions which could conceivably arise during preparation of a proposal, for an Army aircraft, or aircraft related materiel:

1. What is the measure for responsiveness to HEL Standard S-4-65, or what does the government expect in the human factors section of a proposal?

2. What criteria will be used to evaluate the human factors section of a proposal?

3. What does the government consider an acceptable proposal?

The urgency of providing answers to these questions has been highlighted by a recent study (27) which sought to discover the reasons underlying serious technical and management problems which were experienced on a number of major development programs having been established under the Department of Defense Contract Definition (formerly the Project Definition Phase) philosophy (30). In summarizing the lessons learned from contract definition experience, the following may serve to illustrate the importance of providing adequate guidance to the contractor prior to, and during system development. Two basic points most pertinent to the present subject have been extracted from the aforementioned report:

"Perhaps the most important lesson learned is that the quality of the work and planning accomplished by the government during Concept Formulation will determine whether subsequent phases proceed in an orderly fashion or prove difficult."

"When the RFQ's do not contain adequate information on technical and operational objectives and do not prescribe a structure for the information to be supplied, the contractor's proposals tend to be either under-responsive or over-responsive and thus difficult to evaluate."

The evaluation model currently used by USAHEL is shown in block diagram form in Figure 1. It can be seen that the model is divided into two basic elements:

a. Technical

b. Quality Assurance

The Technical portion of the human factors engineering evaluation is concerned with the proposed design (Tables 1 through 4). That is, under this heading we are concerned with determining the extent to which human factors engineering criteria have been applied to the design of the aircraft and its related subsystems.

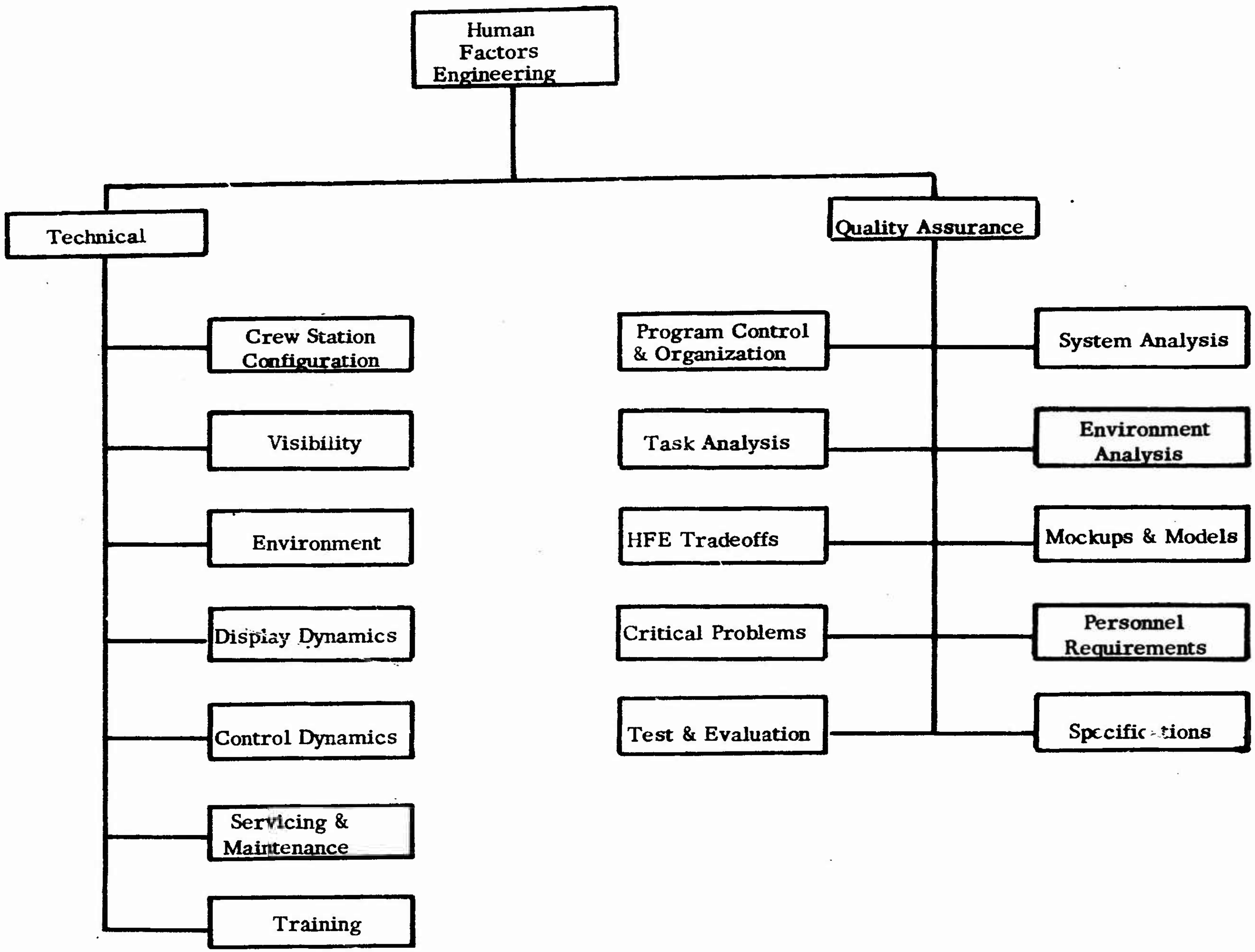

Figure 1. Human Factors Evaluation Model

The Quality Assurance portion of the evaluation (Table 5) is concerned with design only to the extent that it examines the technical substantiating analyses which are provided. It is mainly concerned with the contractor's plans for future work on the design; namely, a detailed human factors engineering program plan.

The term Quality Assurance has generally come to include a number of technical specialties, which are not considered true design activities, but rather design support, or staff functions. The most current basis for this trend is AMCR 702-1, dated 29 July 1965, entitled "Quality Assurance, Independent Product Assessment," (17) and related documents. The primary goal of quality assurance within AMC, as stated by AMCR 702-1, is to provide materiel conforming to the stated requirements specified by the user...."Accordingly, a program providing for up-to-date status and progressive evaluation of product quality is essential to minimize critical quality deficiencies or shortcomings. Independent product assessment is intended to serve this purpose." Consequently, "The primary objectives of assessment are: to focus management and engineering attention to quality requirements such as reliability, maintainability, safety..." Therefore, Quality Assurance embraces at least the following disciplines:

a. Reliability

b. Maintainability

c. Safety

d. Human Factors

e. Value Engineering

f. Quality Control

g. Producibility

Although such disciplines as human factors and value engineering are not explicitly identified as elements of Quality Assurance in AMCR 702-1, they are implicit throughout.

The overall objective of a Quality Assurance program may be defined as the achievement of the proper balance of system quality, effectiveness, simplicity, and cost through an integrated approach to the planning, analysis, review, coordination, documentation, test, inspection, and control for the system. In general terms, the technical evaluation is directed to answering the following fundamental questions which are necessary adjuncts to the mission/system objectives described previously:

a. Does the proposed crew station design exhibit characteristics which are conducive to operator efficiency, comfort and safety from the standpoint of workspace envelope and anthropometry?

b. Does the proposed system incorporate provisions for optimum operator visibility both from the standpoint of vehicle control, and mission performance?

c. Does the proposed system incorporate suitable environmental characteristics which will cause neither undue operator discomfort nor performance decrement?

d. Does the proposed design offer well-integrated, logically arranged, readily understood displays which are consistent with the operator's information requirements and safety for this mission profile?

e. Does the proposed design offer well-integrated, logically arranged, easily operated controls which are consistent with the operator's response requirements and safety for the mission profile?

f. Does the proposed design incorporate characteristics which provide for ease of system and subsystem servicing, checkout and replacement?

g. Does the proposed design provide for relative ease of training, in terms of consistency with contemporary systems?

In short, equipment should be simple, yet effective; there should be a minimum of "gold plating" in the design.

In the same general terms as above, the Quality Assurance/Human Factors Engineering evaluation is directed to answering the following questions:

a. Does the contractor delineate a strong human factors organization, and does he plan to use accepted program control techniques dealing with reports, specifications and data?

b. Does the contractor plan to include, and has he to-date shown, the capability and methodology for integrating human factors engineering in system analyses?

c. Does the contractor plan to conduct and has he to-date shown, acceptable human factors analytic techniques, such as task, time-line, link and training requirements analyses?

d. Does the contractor plan to conduct, and has he to-date shown, analyses of specific operator/environment problems which can be predicted with some degree of assurance?

e. Does the contractor plan to conduct and has he to-date shown, tradeoff analyses which specifically include consideration of human engineering factors?

f. Does the contractor plan to use and has he used to-date, accepted mockup techniques as a design tool for assuring incorporation of human engineering factors?

g. Does the contractor show an awareness of critical human factors problem areas associated with the system, and does he plan to investigate them, or has an investigation already been made?

h. Does the contractor plan to investigate or has he shown preliminary estimates in his proposal of personnel requirements and specific training problems?

i. Does the contractor plan to utilize human factors engineering techniques during system test and evaluation activities?

j. Does the contractor plan to incorporate accepted human factors related military specifications in his design specifications? To what extent have human engineering requirements been included to date?

The above general questions are all within the intent of HEL Standard S-4-65. Needless to say, the degree to which these questions can be answered affirmatively, and the degree to which the contractor has detailed his answers, will result in a proportionately more acceptable score in an evaluation.

There is of course another factor used during an evaluation which influences the final human factors engineering rating which is given to a specific proposal. This is the weighting factor which is applied to each evaluation element. However, the weight which is applied to each of the above questions is necessarily a function of the following:

a. Specific directives of individual Source Selection Evaluation Board chairmen.

b. Specific problem areas discovered during previous design proposals.

c. Specific system characteristics or military requirements which inherently emphasize or de-emphasize certain of the human factors engineering evaluation elements.

d. Particular bias of the individual human factors engineering proposal evaluator.

Certainly the basic structure of the evaluation model needs considerable elaboration before a complete understanding of its constituent elements can be achieved. Rather than launch into a detailed dissertation of each of the "subfactors" of the model, it is hoped that presentation of the information in tabular form, supplemented by judicious use of examples, will suffice.

Tables 1 through 5 have been developed in order to delineate the individual subfactors of the model, and representative criterion documents to support the subfactors. It is important to note that the documents shown in the tables are by no means exhaustive. They are merely meant to represent a minimum number of requirement-setting and methodological documents with which both government and contractor human factors personnel should be intimately familiar. It is obvious through a cursory glance at the tables that certain of the elements of the model are not adequately supported by human factors engineering evaluation criteria. In some cases there are no criteria whatsoever. This unfortunate situation will hopefully be alleviated within the near future through the development of a U.S. Army Aviation Human Factors Design Handbook by HEL. Until such time as this document becomes available, evaluators (both government and contractor) must rely upon technical judgment and relevant source material. It should also be noted that many of the existing specifications and standards are continually undergoing revision and consolidation. It is intended that the present evaluation model will be periodically revised to reflect current design philosophy and practice.

With regard to Table 5, which deals exclusively with the Quality Assurance aspects of the human factors program, two points should be stressed. First, the purpose of delineating certain methodological sources is not to restrict the evaluator or the contractor to specific analytic techniques. The basis for identifying the criterion documents is to assure that the fundamental elements of human factors analyses are not overlooked. Advanced and/or inventive analytic techniques are greatly encouraged. Second, relevant USAF personnel subsystem documents are shown because of their overall thoroughness of coverage of the human factors area. The Army has not instituted a comparable human factors/personnel subsystem program.

It may be noted through an examination of Tables 1 through 5 that no specific mention is made of aircraft or personnel safety. It is obvious that safety is most definitely an important aspect of the total human factors area. It is for this reason, then, that human factors engineers must closely coordinate safety problems with personnel of the U.S. Army Board for Aviation Accident Research (USABAAR).

As previously mentioned, even the subfactors shown in Tables 1 through 5 are not inclusive of all of the considerations to be taken into account by the human factors evaluator. Several examples are given in the remaining pages of this section so as to give the reader a fuller understanding of the evaluation model.

Example 1

The area of Seating and Furnishings (Table 1) is, of course, a major area within the overall crew station configuration element. It necessarily embodies a host of considerations which the human factors evaluator must examine. For the sake of convenience, some of the considerations which might be subsumed under Seating and Furnishings are framed as questions, or checklist items, as follows:

1. Crew Seats

a. Is the vertical and fore and aft adjustment accomplished together or separately?

b. In what increments can the adjustment be made?

c. How is seat adjustment accomplished?

d. Where is the adjustment control located?

e. For what equipment is the seat designed?

f. What type of restraint system is used?

g. Is the seat equipped with a correctly mounted inertia reel with a "stalock" feature?

h. Is there an indicator provided so that the crew can determine correct eye level?

2. Ejection Seats

a. Can the seat be ejected from any point in its adjustment?

b. What is the relation between seat and canopy during ejection?

c. What is the angle at which the seat is ejected?

d. What forward and side clearances are present during ejection?

e. What type of handgrips are provided?

f. Is the shoulder harness automatically locked prior to ejection?

g. What leg retention is provided?

h. Is an automatic belt release provided?

i. Is an automatic parachute opener provided?

j. What ground safety devices are provided?

3. Passenger and Troop Accommodations

a. What type of seats are provided?

b. What adjustment is provided for the seats?

c. What type of safety belts are provided?

d. Are shoulder harness and inertia reels provided?

e. What equipment are seats designed for?

f. What type of litters are provided?

g. What is the vertical distance between litters?

h. What is the height of the topmost litter above an inflight stable surface?

i. What is the aisle space between litters?

4. Furnishings

a. What toilet facilities are provided?

b. What lockers for food are provided?

c. What drinking water containers are provided?

d. What cooking facilities are provided?

e. Are relief tubes provided?

f. Are ashtrays provided?

Example 2

Under the element Control Dynamics (Table 3) the factor of Vehicle Control and Aircraft Systems can be amplified in the same manner as in Example 1. The subfactors, namely: control movement, marking and

placarding, coding and scaling, redundancy and guarding apply to whatever controls are provided for actually operating the aircraft on the ground, and inflight. Some of the considerations which should be examined are again shown as questions as follows:

1. Primary Flight Controls

a. What type of controls are provided for lateral, directional, and longitudinal control?

b. What are the travel limits of the controls?

c. What type of pedal adjustment is provided?

d. If pedals are separately adjustable, have means been provided to indicate relative position to the pilot?

e. How much pedal adjustment is provided?

f. Does tilt of pedals permit comfortable application of brakes at any pedal position?

g. What switches are located on the grips of the primary flight controls?

h. What type of control boost is provided?

i. How does the pilot actuate the emergency boost system?

j. What type of trim controls are provided?

k. Where are standby trim tab actuating controls located?

2. Miscellaneous Controls

a. What type of high lift device is provided?

b. Where is the control located?

c. What type of control is provided for actuation of speed brakes or spoilers?

d. Can intermediate positions be selected?

e. What type of autopilot controls are provided?

f. Where are autopilot controls located?

g. What type of landing gear control is provided?

h. What means are provided for preventing inadvertent ground operation?

i. What type of emergency landing gear extension control is provided?

j. Are there provisions for the following:

(1) Flight control lock?

(2) Tail wheel lock?

(3) Emergency brake control?

(4) Parking brake control?

(5) Canopy control?

(6) Nosewheel steering control?

(7) Rotor clutch control?

(8) Rotor brake control?

It can be noted that the above considerations apply specifically to aircraft flight control systems, within the element Control Dynamics. However, similar questions dealing with other aspects of Vehicle Control and Aircraft Systems can be similarly developed. Controls for hydraulics, electrical, pneumatic, and environmental control subsystems should be evaluated under this factor.

Example 3

Within the Quality Assurance (Table 5) portion of the evaluation, it is considered appropriate to define the factor Program Control and Organization. Again, some of the considerations which should be examined are shown as questions:

Program Control and Organization

a. Has a detailed schedule of the human factors program been provided to show anticipated reporting points, program milestones and the like?

b. Has the human factors program been integrated in system and PERT planning?

c. Does the program provide for maintaining human factors data and records so that government personnel may readily assess progress of the contractor human factors effort?

d. Is the human factors program well-integrated with other disciplines of Quality Assurance? Are their respective roles well-defined so as to avoid unnecessary duplication of effort?

e. Does the contractor human factors section or department actively participate in system design reviews?

f. Have provisions been made for assuring subcontractor compliance with applicable human factors requirements?

g. If human factors consultants are planned are their responsibilities and efforts clearly defined?

h. Does the contractor human factors organization function as reviewers of layout drawings, specifications, and Engineering Change Proposals? Do they have "sign-off" authority?

i. Is the human factors program integrated in the overall design, development and test activities?

j. What is the overall authority and function of the human factors organization?

k. What are the qualifications of human factors personnel and extent of their assignment to the program?

The above examples are meant to be illustrative of the kinds of considerations which would be examined during an evaluation. These considerations are not meant to be, in either of the three examples given, complete lists. By reviewing the applicable documents referenced in Tables 1 through 5, it is possible to construct similar lists of questions for each of the subfactors shown.

Two important implications can be recognized through an examination of the tables. That is with regard to the relative, and in some cases total, lack of criteria for certain of the evaluation factors. The most obvious implication is that contractors should be prepared to develop complete substantiating analyses for those factors. The other implication is that the proposed Army Human Factors Aviation Handbook will be developed so that areas lacking suitable criteria will be more completely specified.

Earlier in the report reference was made to the need for evaluators to be well versed in mission requirements and overall operational suitability characteristics of the system. It is evident that the evaluation procedure must take into account each of the segments comprising the stated mission profiles of the system. By this it is meant that for each subfactor of the model, the evaluator must have a working knowledge of operator task performance requirements for each mission segment in order that a satisfactory judgment can be made as to the technical adequacy of human factors engineering.

Possibly the most prevalent and indeed justifiable criticism of the human factors evaluation model is that it is not quantitative. That is, it does not give the evaluator a set of upper and lower limits, or measurable values by which one system can be evaluated or scored against another. It is an accepted fact that the adequacy of human factors engineering in a system design has been largely determined by professional judgment. A number of techniques have been proposed by workers in the field of human factors, for better quantitative assessment of display design. For example, one technique developed by Siegel et al. (124) shows considerable promise. However, until such techniques can be fully developed and thoroughly validated, much of the human factors engineering evaluation process will be dependent upon individual technical judgment and experience.

CONCLUSIONS

In the previous pages of this report, mention was made of the need to answer three basic questions which might arise during proposal preparation. These questions are repeated here for the reader's convenience:

a. What is the measure for responsiveness to HEL Standard S-4-65, or what does the government expect in the human factors section of a proposal?

b. What criteria will be used to evaluate the human factors section of a proposal?

c. What does the government consider an acceptable proposal?

It is clear that the Evaluation Model (Tables 1 through 5) is the basis for a fully responsive proposal. Certainly if a prospective contractor utilizes the criterion documents delineated in the model, and if the data requirements are met, then a proposal will be considered responsive. The documents referenced in Tables 1 through 5 will be considered as the major sources for technical and Quality Assurance criteria for an evaluation. An acceptable proposal is one in which all the elements of the model are qualitatively covered. Thorough coverage of all the elements and detailed analyses to support the design will most likely result in a proposal, which is fully responsive to HEL Standard S-4-65.

The following conclusions are presented:

a. The Evaluation Model does serve the immediate purpose for which it was designed. That is, it should function as a useful tool for contractor and government evaluators. It further should provide some measure of assurance that the criteria used for evaluating a system are the same as those used for specifying requirements.

b. The Evaluation Model does not pretend to be a panacea; that is, it is far from being a detailed specification of technical requirements for human factors engineering. It is a starting point and definitely points up the need for further work to be done in specifying human factors requirements.

c. The Evaluation Model outlines areas in which future research should be directed, in order to ultimately achieve quantitative system evaluation procedures and criteria for human factors.

In summary, if one would attempt to describe the U.S. Army Human Engineering Laboratories' position on the human factors aspects of aviation, it could be best expressed by taking some liberties with a passage from "Airpower, the Decisive Force in Korea" (127). With apologies to the author, this writer has attempted to rephrase an eloquent exposition of man's capabilities in the air, within the context of Army aviation.

For the Army aviator, air mobile combat is still a personal challenge. "Since the convulsive battle has been joined, no electronic guiding device yet developed can substitute for a pair of sharp eyes, skilled senses and an alert human mind capable of translating into stick and rudder actions the 'decisions' which are necessary for '...mission accomplishment...' "Sober analysis of air warfare and homage to technological progress sometimes lose sight of this man. He is yet the physical, mental, and emotional mechanism that can transcend the insensate limitations of highly developed technology to permit selective reaction, subtle interpretation, and command decision. The greatest technical accomplishments have merely supplemented his skill, ingenuity, and adaptability."

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TABLE I

AVIATION HUMAN FACTORS ENGINEERING CRITERIA & DATA REQUIRED FOR TECHNICAL EVALUATION

EVALUATION MODEL			EVALUATION CRITERIA			
EVALUATION ELEMENTS	EVALUATION FACTORS	EVALUATION SUBFACTORS	MILITARY SPECIFICATIONS	MILITARY STANDARDS	DATA REQUIRED & OTHER EVALUATION TECHNIQUES	MISCELLANEOUS DOCUMENTS
CREW STATION CONFIGURATION	ANTHROPOMETRY	COCKPIT DIMENSIONS OVERALL ENVELOPE CONTROL ADJUSTMENT	MIL-M-8650 [74]	MS-33573 [114] MS-33574 [115] MS-33575 [116] MS-33576 [117] PROPOSED MIL-STD AIRCREW STATION GEOMETRY [100]	MOCKUP EVALUATION INBOARD PROFILE DRAWINGS	TECH REPORT EP-150 [117] HIAD [9] WADC TR 52-321 [45] FAR, PARTS 23,25,27,29 [35,36,34,37] WADC TR 54-520 [46]
	CREW COORDINATION	INTER-CREW VISIBILITY "TOGETHERNESS" MIRRORS INTERCOM			MOCKUP EVALUATION DETAILED ANALYSIS	
	SEATING / FURNISHING	ESCAPE PROVISIONS STRUCTURAL INTEGRITY COMFORT FEATURES BIOMECHANICAL ASPECTS RESTRAINT SYSTEM ADJUSTMENT FEATURES PASSENGER ACCOMODATIONS LITTER, TOILET, GALLEY PROVISIONS	MIL-S-5822 [82] MIL-M-8650 [74] MIL-S-18471 [86] MIL-S-18619 [87] MIL-S-25073 [88] MIL-S-7832 [84] MIL-S-9479 [85] MIL-C-6779 [55] MIL-H-65368 [60] MIL-R-82368 [80]		MOCKUP EVALUATION DETAILED ANALYSIS	HIAD (AFSCM 80-3) [9] AVCIR REPORT 62-12 [13] TRECOM REPORT 64-3 [129] WADC TR 55-159 [29]
	INGRESS / EGRESS	ESCAPE PROVISIONS EXIT DIMENSIONS STEPS & HANDHOLDS STRUCTURAL INTERFERENCE CANOPY OPERATION	MIL-A-25165 [53] MIL-M-8650 [74]		MOCKUP EVALUATION DETAILED ANALYSIS	HIAD (AFSCM 80-1) [9]
	STOWAGE	ARMOR MAPS & DOCUMENTS SURVIVAL EQUIPMENT PERSONAL EQUIPMENT	MIL-M-8650 [74]		MOCKUP EVALUATION INBOARD PROFILE DRAWINGS	HIAD (AFSCM 80-1) [9]
	PROTECTION	BODY ARMOR SEAT & STRUCTURAL ARMOR CANOPY & WINDSHIELD SURVIVAL EQUIPMENT OXYGEN EQUIPMENT			MOCKUP EVALUATION DETAILED ANALYSIS	HIAD (AFSCM 80-1) [9] TRECOM TR 63-79 [128]
	INJURY POTENTIAL	SHARP PROJECTIONS EQUIPMENT INTERFERENCE STRUCTURAL INTEGRITY FIRE PROTECTION CRASH PROTECTION			MOCKUP EVALUATION DETAILED ANALYSIS	HEL-TECH MEMO 21-62 [44]
COCKPIT VISIBILITY	VISIBILITY ENVELOPE	OVER-THE-NOSE OVER-THE-SIDE REARWARD AZIMUTH CANOPY FOGGING WINDSHIELD DEICING RAIN REMOVAL	MIL-M-8650 [74] MIL-T-5842 [102]	MIL-STD-850 (PROPOSED) [98]	MOCKUP EVALUATION DETAILED DRAWING DETAILED ANALYSIS	HIAD (AFSCM 80-1) [9]
	CANOPY CONTOURING	BODY CLEARANCES VISUAL ANGLES DISTORTION			DETAILED DRAWINGS DETAILED ANALYSIS	WADC TR-58-399 [134]
	FRAME INTERFERENCE	SIZE OF FRAMES POSITIONING OF FRAMES EQUIPMENT LOCATION			DETAILED DRAWINGS DETAILED ANALYSIS	WADC TR-58-399 [134]

TABLE 2

AVIATION HUMAN FACTORS ENGINEERING CRITERIA & DATA REQUIRED FOR TECHNICAL EVALUATION

EVALUATION MODEL			EVALUATION CRITERIA			
EVALUATION ELEMENTS	EVALUATION FACTORS	EVALUATION SUBFACTORS	MILITARY SPECIFICATIONS	MILITARY STANDARDS	DATA REQUIRED & OTHER EVALUATION TECHNIQUES	MISCELLANEOUS DOCUMENTS
ENVIRONMENT	NOISE	INFLIGHT CONTINUOUS NOISE IMPULSE NOISE ATTENUATION DEVICES SOUNDPROOFING	MIL-A-8806 [52] MIL-S-6144 [83]		DETAILED ANALYSIS	HEL-STD-S-1-63B [26] AFR 160-3A [8] WADC TR-52-204 [48] NASA LIFE SCIENCES DATA BOOK [119] AIR-290-80 FR-225 [38]
	VENTILATION / TEMPERATURE CONTROL	HEATING SYSTEM COOLING SYSTEM SUNSHADES AUXILIARY COOLING SYSTEM		MIL-STD-210A-1 [94]	DETAILED ANALYSIS	HIAPSD (AFSCM 80-3) [10] NASA LIFE SCIENCES DATA BOOK [119] AIR-290-80 FR-225 [38]
	BIOMECHANICAL	VIBRATION ACCELERATION DISORIENTATION	MIL-H-8501A [61]		DETAILED ANALYSIS	HIAPSD (AFSCM 80-3) [10] NASA LIFE SCIENCES DATA BOOK [119] AIR-290-80 FR-225 [38]
	ILLUMINATION	EXTERNAL SOURCES INSTRUMENT LIGHTING AUXILIARY LIGHTING OTHER COMPARTMENT LIGHTING	MIL-L-6503D [70] MIL-L-25467A [72] MIL-L-006730B [71]	MIL-STD-803A [97]	LIGHTING MOCKUP DETAILED ANALYSIS	HIAPSD (AFSCM 80-3) [10] NASA LIFE SCIENCES DATA BOOK [119] AIR-290-80 FR-225 [38]
	TOXICITY	GUN GAS INGESTION ENGINE EXHAUST CBR PROTECTION PRESSURIZATION			DETAILED ANALYSIS DETAILED DRAWINGS	HIAPSD (AFSCM 80-3) [10] NASA LIFE SCIENCES DATA BOOK [119] AIR-290-80 FR-225 [38] USAF PAMPHLET 161-2-1 [130]
DISPLAY DYNAMICS	NAVIGATION	INFORMATION CONTENT / SIZE MARKING / PLACARDING CODING / SCALING ILLUMINATION MOVEMENT REDUNDANCY	MIL-C-25050 [56] MIL-I-5997B [60] MIL-L-5667A [67] MIL-L-6503D [70] MIL-L-25467 [72] MIL-L-27160 [73] MIL-M-8650A [74] MIL-M-18012B [75] MIL-P-007788C [77]	MIL-STD-12B [91] MS-33572 [113] MIL-STD-803A [97] MIL-STD-130B [92]	MOCKUP EVALUATION	
	VEHICLE CONTROL & AIRCRAFT SYSTEMS	SAME AS ABOVE	SAME AS ABOVE	MIL-STD-12B [91] MIL-STD-803A [97] MS-33572 [113] MIL-STD-130B [92]	SAME AS ABOVE	
	FIRE CONTROL ARMAMENT SURVEILLANCE	SAME AS ABOVE	SAME AS ABUVE	MIL-STD-12B [91] MIL-STD-803A [97] MIL-STD-130B [92]	SAME AS ABOVE	
	COMMUNICATIONS	SAME AS ABOVE	SAME AS ABOVE	MIL-STD-12B [91] MIL-STD-803A [97] MIL-STD-130B [92]	SAME AS ABOVE	
	WARNING	INFORMATION CONTENT / SIZE LOCATION MARKING / PLACARDING ILLUMINATION MOVEMENT REDUNDANCY SIGNAL TYPE / DURATION	SAME AS ABOVE	MIL-STD-12B [91] MIL-STD-411A [96] MIL-STD-803A [97] MIL-STD-130B [92]	SAME AS ABOVE	
	FUEL MANAGEMENT	SAME AS ABOVE	SAME AS ABOVE	MIL-STD-12B [91] MIL-STD-803A [97] MIL-STD-130B [92]	SAME AS ABOVE	
	INTEGRATION	CONTROL / DISPLAY RELATIONSHIPS ARRANGEMENT LOCATION REDUNDANCY	SAME AS ABOVE	MIL-STD-803A [97]	DETAILED DRAWINGS DETAILED HFE ANALYSIS STATE-OF-THE-ART TECHNIQUES DISPLAY EVALUATIVE INDEX (SIEGEL) MOCKUP EVALUATION	WOODSON [133] MORGAN, COOK, CHAPANIS & LUND [111] McCORMICK [49]

TABLE 3

AVIATION HUMAN FACTORS ENGINEERING CRITERIA & DATA REQUIRED FOR TECHNICAL EVALUATION

EVALUATION MODEL			EVALUATION CRITERIA			
EVALUATION ELEMENTS	EVALUATION FACTORS	EVALUATION SUBFACTORS	MILITARY SPECIFICATIONS	MILITARY STANDARDS	DATA REQUIRED & OTHER EVALUATION TECHNIQUES	MISCELLANEOUS DOCUMENTS
CONTROL DYNAMICS	NAVIGATION	CONTROL MOVEMENT MARKING / PLACARDING CODING / SCALING REDUNDANCY GUARDING	MIL-C-6781 [54] MIL-K-25049 [69] MIL-M-8650A [74] MIL-M-18012B [75]	MIL-STD-203D [93] MIL-STD-250B [95] MIL-STD-803A [97]	MOCKUP EVALUATION	
	VEHICLE CONTROL & AIRCRAFT SYSTEMS	CONTROL MOVEMENT MARKING / PLACARDING CODING / SCALING REDUNDANCY GUARDING FEEDBACK	SAME AS ABOVE	MIL-STD-203D [93] MIL-STD-250B [95] MIL-STD-803A [97]	SAME AS ABOVE	
	FIRE CONTROL ARMAMENT SURVEILLANCE	CONTROL MOVEMENT MARKING / PLACARDING CODING / SCALING REDUNDANCY GUARDING	SAME AS ABOVE	MIL-STD-203D [93] MIL-STD-250B [95] MIL-STD-803A [97]	SAME AS ABOVE	
	COMMUNICATIONS	SAME AS ABOVE	SAME AS ABOVE	MIL-STD-203D [93] MIL-STD-250B [95] MIL-STD-803A [97]	SAME AS ABOVE	
	EMERGENCY	SAME AS ABOVE	SAME AS ABOVE	MIL-STD-203D [93] MIL-STD-250B [95] MIL-STD-411A [96] MIL-STD-803A [97]	SAME AS ABOVE	
	FUEL MANAGEMENT	SAME AS ABOVE	SAME AS ABOVE	MIL-STD-203D [93] MIL-STD-250B [95] MIL-STD-803A [97]	SAME AS ABOVE	
	INTEGRATION	CONTROL / DISPLAY RELATIONSHIPS ARRANGEMENT LOCATION REDUNDANCY	SAME AS ABOVE	MIL-STD-203D [93] MIL-STD-250B [95] MIL-STD-803A [97]	DETAILED DRAWINGS DETAILED HFE ANALYSES STATE-OF-THE-ART TECHNIQUES MOCKUP EVALUATION	WOODSON [133] MORGAN, COOK, CHAPANIS & LUND [111] McCORMICK [49]
SERVICING & MAINTENANCE	EQUIPMENT ACCESS	ACCESS FOR REPLACEMENT ACCESS FOR ADJUSTMENT PLATFORMS & STEPS		MIL-STD-1247 [99] MIL-STD-803A [97]	MOCKUP EVALUATION DETAILED DRAWING DETAILED HFE ANALYSES	WADC TR-56-218 [40] WADC TR-61-381 [11] AIR-290-60FR-225 [38] RADC-TR-55-83 [126]
	SERVICING PROCEDURES	TURNAROUND (ORGANIZATIONAL LEVEL) DIRECT SUPPORT LEVEL		SAME AS ABOVE	SAME AS ABOVE	
	CHECKOUT PROCEDURES	TURNAROUND (ORGANIZATIONAL LEVEL) DIRECT SUPPORT LEVEL		SAME AS ABOVE	SAME AS ABOVE	
	GROUND HANDLING PROCEDURES	ENGINE OFF ENGINE OPERATION JACKING MOORING		SAME AS ABOVE	SAME AS ABOVE	
	FAULT ISOLATION	INFLIGHT ORGANIZATIONAL SUPPORT DIRECT SUPPORT		MIL-STD 803A [97]	SAME AS ABOVE	WADC TR-56-218 [40] WADC TR-61-381 [11] AIR-290-60FR-225 [38] RADC-TR-55-83 [126]

TABLE 4

AVIATION HUMAN FACTORS ENGINEERING CRITERIA & DATA REQUIRED FOR TECHNICAL EVALUATION

EVALUATION MODEL			EVALUATION CRITERIA			
EVALUATION ELEMENTS	EVALUATION FACTORS	EVALUATION SUBFACTORS	MILITARY SPECIFICATIONS	MILITARY STANDARDS	DATA REQUIRED & OTHER EVALUATION TECHNIQUES	MISCELLANEOUS DOCUMENTS
TRAINING	FLIGHT CREW	TOTAL FLIGHT TIME REQUIRED CREW CROSS TRAINING FLIGHT HOURS PER MONTH SPECIALIZED FLIGHT TRAINING GUNNERY TRAINING SPECIALIZED ELECTRONICS EQUIPMENT TRAINING COMPARISON WITH CURRENT COURSE CURRICULA	MIL-T-27382A [106]	AFBM 59-17C [2] AFSCM 80-3 (HIAPSD) [10]	TASK & SKILL ANALYSIS TRAINING REQUIREMENTS ANALYSIS MANNING ESTIMATES	ASD TR-61-533 [28] TR-56-389 [118]
	MECHANICS	ORGANIZATIONAL LEVEL DIRECT SUPPORT LEVEL GENERAL SUPPORT LEVEL NUMBER OF PERSONNEL REQUIRED COMPARISON WITH CURRENT COURSE CURRICULA	MIL-T-27382A [106]	AFBM 59-17C [2] AFSCM 80-3 (HIAPSD) [10]	SAME AS ABOVE	ASD TR-61-533 [28]
	ARMORERS	ORGANIZATIONAL LEVEL DIRECT SUPPORT LEVEL GENERAL SUPPORT LEVEL NUMBER OF PERSONNEL REQUIRED COMPARISON WITH CURRENT COURSE CURRICULA	MIL-T-27382A [106]	AFBM 59-17C [2] AFSCM 80-3 (HIAPSD) [10]	SAME AS ABOVE	ASD TR-61-533 [28]
	AVIONICS SPECIALISTS	ORGANIZATIONAL LEVEL DIRECT SUPPORT LEVEL GENERAL SUPPORT LEVEL NUMBER OF PERSONNEL REQUIRED COMPARISON WITH CURRENT COURSE CURRICULA	MIL-T-27382A [106]	AFBM 59-17C [2] AFSCM 80-3 (HIAPSD) [10]	SAME AS ABOVE	ASD TR-61-533 [28]
	TRAINING SUPPORT	SCHOOL AIRCRAFT REQUIREMENTS MISSION SIMULATOR PROCEDURAL TRAINER PART TASK TRAINER TRAINING AIDS	MIL-T-27382A [106] MIL-T-4860C [101] MIL-T-6328F [103] MIL-T-8823 [104] MIL-T-9212A [105] MIL-T-27474 [107]	AFBM 59-17C [2] AFSCM 80-3 (HIAPSD) [10]	SAME AS ABOVE	ASD TR-61-549 [41] ASD TR-61-550 [39] ASD TR-61-533 [28] WADC TR-56-527 [121]
	ADDITIONAL MOS REQUIREMENTS	FLIGHT CREW MECHANICS ARMORERS AVIONICS SPECIALISTS	MIL-D-26239A	AFBM 58-18C [1]	DETAILED ANALYSIS	AR 611-101 [19] AR 611-112 [20] AR 611-201 [21]

TABLE 5

AVIATION HUMAN FACTORS ENGINEERING CRITERA & DATA REQUIRED FOR QUALITY ASSURANCE EVALUATION

EVALUATION MODEL			EVALUATION CRITERIA		
EVALUATION ELEMENTS	EVALUATION FACTORS	EVALUATION SUBFACTORS	RELEVANT MILITARY SPECIFICATIONS & STANDARDS	RELEVANT PERSONNEL SUBSYSTEM GUIDES	RELEVANT REFERENCE DOCUMENTS
QUALITY ASSURANCE	*PROGRAM CONTROL & ORGANIZATION*	HFE REPORTS DETAILED SCHEDULE PERT INTEGRATION PROVISIONS FOR HFE DATA HFE DESIGN REVIEWS SUBCONTRACTOR COMPLIANCE HFE CONSULTANT TASKS HFE DRAWING APPROVAL HFE INTEGRATION WITH OTHER QUALITY ASSURANCE ELEMENTS HFE ORGANIZATION & PERSONNEL	HEL-STD-S-4-65[25] MIL-H-27894A[65] MIL-H-46819[66] MIL-M-26512[76] MIL-Q-9858A[79] MIL-P-25996[78] MIL-R-27542A[81] MIL-S-58077[90] MIL-S-38130[89] MIL-V-38352[108]	HIAPSD (AFSCM-80-3)[10] AFBSD EXH 61-99[5]	WADC TR 61-739[42] MEISTER & RABIDEAU[51] AMCR-11-26 SCL-1787A[125]
	SYSTEM ANALYSIS	FUNCTIONAL FLOW CHART END ITEM DESIGN FORMS FUNCTIONAL ANALYSES FUNCTIONAL ALLOCATION SOURCES OF HUMAN ERROR (PREDICTED) PERSONNEL PERFORMANCE REQUIREMENTS	HEL-STD-S-4-65[25] MIL-D-9310B[57] MIL-H-22174[62] MIL-H-25946[63] MIL-H-26207[64] MIL-H-27894A[65]	HIAPSD (AFSCM-80-3)[10] AFBSD EXH 62-101[6]	WADC TR-56-488[132] WADC TR-59-784[122]
	TASK ANALYSIS	MISSION ANALYSIS FUNCTIONS ANALYSIS INFORMATION REQUIREMENTS ANALYSIS INFORMATION-DECISION-ACTION DIAGRAMS TASK & SKILL ANALYSIS TIME LINE ANALYSIS LINK ANALYSIS TRAINING REQUIREMENTS ANALYSIS	HEL-STD-S-4-65[25] MIL-H-22174[62] MIL-H-25946[63] MIL-H-26207[64] MIL-H-27894A[65]	HIAPSD (AFSCM-80-3)[10] AFBM EXH 60-65A[4] AFBM EXH 63-19[7]	WADC TR-53-137[109] WADC TR-56-488[132] HEL TECHNICAL MEMORANDUM 13-64[24] MORELAND[112]
	ENVIRONMENT ANALYSIS	INFLIGHT ENVIRONMENT GROUND ENVIRONMENT	HEL-STD-S-4-65[25] MIL-H-27894A[65]	HIAPSD (AFSCM-80-3)[10]	
	TRADEOFFS	FUNCTION ASSIGNMENTS (MAN / MACHINE) OPERATOR ASSIGNMENTS (MAN / MAN) DESIGN SELECTION	HEL-STD-S-4-65[25] MIL-H-27894A[65]	HIAPSD (AFSCM-80-3)[10]	
	MOCKUPS	STATIC MOCKUPS FUNCTIONAL MOCKUPS SCALE MODELS DYNAMIC SIMULATION SPECIAL STUDIES LIGHTING MOCKUPS	HEL-STD-S-4-65[25] MIL-H-27894A[65] MIL-M-8650[74] MIL-P-25396[78]	HIAPSD (AFSCM-80-3)[10]	ASD TR-61-545[47] WADC 54-160[22] WADC 56-171[32] WADC 56-172[33] WADC 57-582[31] WADC 56-524[50]
	CRITICAL PROBLEMS	TECHNICAL PROBLEMS SPECIFICATIONS COMPLIANCE (PROGRAM REQUIREMENTS)	HEL-STD-S-4-65[25] MIL-H-27894A[65]	HIAPSD (AFSCM-80-3)[10]	
	PERSONNEL REQUIREMENTS	MANNING ESTIMATES SKILL REQUIREMENTS TRAINING REQUIREMENTS ADDITIONAL MOS REQUIREMENTS JOB AIDS	HEL-STD-S-4-65[25] MIL-D-26239A[58] MIL-H-27894A[65] MIL-T-27382[106]	HIAPSD (AFSCM-80-3)[10] AFBSD EXH 59-17C[2] AFBM EXH 58-18C[1] AFBM EXH 63-19[7]	ASD TR 61-533[28] AMRL-TDR-63-110[43] WADC-TR-54-563[110]
	TEST & EVALUATION	HFE TEST OBJECTIVES HFE TEST METHODS	HEL-STD-S-4-65[25] MIL-H-2789A[65]	HIAPSD (AFSCM-80-3)[10] AFBM EXH 60-1[3]	WADC 60-36[123] MEISTER & RABIDEAU[51] AMRL-TDR-62-105[131]
	SPECIFICATIONS	SYSTEM SPECIFICATION DETAIL MODEL SPECIFICATION CONFIGURATION END ITEM SPECIFICATION			AMCR 11-26[16]